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Bony Morphology of Femoroacetabular Impingement in Young Female Dancers and Single-Sport Athletes

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Background: Femoroacetabular impingement (FAI) is a painful and limiting condition of the hip that is often seen in young athletes. Previous studies have reported a higher prevalence of this disorder in male athletes, but data on the structural morphology of adolescent and young adult female athletes, specifically those involved in dance, are lacking.

Purpose: (1) To investigate the radiographic morphology of FAI deformities in adolescent and young adult female single-sport dance and nondance athletes and (2) to examine the differences in the radiographic findings between these 2 groups.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A retrospective chart review of 56 female single-sport athletes 10 to 21 years of age with a diagnosis of FAI within a single-sports medicine division of a pediatric academic medical center was performed. Acetabular index (AI), lateral center-edge angle (LCEA), crossover sign, and ischial spine sign were measured bilaterally on anteroposterior radiographs; alpha angle (AA) was measured on lateral films, and anterior center-edge angle (ACEA) was measured on false-profile films. Independent *t* tests and Mann-Whitney *U* tests were used to compare mean angle measurements between dance and nondance athletes. Dichotomized categorical variables and crossover and ischial spine signs were analyzed between dance and nondance athletes by applying a chi-square test. Statistical significance was set as $P < .05$ a priori.

Results: Significant differences in angle measurements were noted. AA was significantly lower in the dancers compared with the nondance athlete group ($49.5^\circ \pm 6.0^\circ$ vs $53.9^\circ \pm 7.3^\circ$, $P = .001$). The LCEA and ACEA of dance athletes were significantly greater compared with nondance athletes ($33.8^\circ \pm 6.7^\circ$ vs $30.9^\circ \pm 5.8^\circ$ [$P = .016$] and $36.0^\circ \pm 8.1^\circ$ vs $32.3^\circ \pm 7.0^\circ$ [$P = .035$], respectively). No significant difference in AI was seen between the 2 cohorts ($5.0^\circ \pm 4.0^\circ$ for dancers vs $5.9^\circ \pm 3.4^\circ$ for nondancers, $P = .195$).

Conclusion: Significant differences existed in the radiographic bony morphology of young female single-sport dance athletes compared with nondance athletes with FAI. In dance athletes, symptoms were seen in the setting of normal bony morphology.

Keywords: hip; femoroacetabular impingement; female athletes; dance; ice hockey; soccer; running

Femoroacetabular impingement (FAI) is a structural disorder of the hip that results in abnormal forces between the femoral neck and acetabulum and/or acetabular labrum. This concept is well recognized as a factor in the development of future hip osteoarthritis (OA).[10,15] Multiple studies have shown that the athletic population appears to have a higher prevalence of FAI, specifically cam-type deformities, than do nonathletes.[1,6,11,17,21]

The demands of the dance athlete are such that they are expected to attain supraphysiologic hip joint range of motion to meet the requirements of both simple and advanced maneuvers. Specifically, the high degree of hip flexion, external rotation, extension, and abduction may place undue stress on the intra- and periarticular structures of the hip joint, even in the setting of normal bony morphology.[20] Furthermore, the young dancer may develop techniques to force certain positions, increasing risk for injury and pain. While a dancer's inherent range of joint motion can be maintained over time, there is evidence to suggest that passive joint range of motion is fixed and unlikely to improve with age.[28]

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The area of sports specialization has also garnered increased attention in recent years. Early specialization, defined as intense year-round training in a single sport at a young age while excluding others,[16] may increase the risk of overuse injuries, psychological stress, and burnout. This period may also be a time during which sport-related stresses influence the development of the bony morphology of the hip. Evidence suggests that there is a distinct period during which the cam-type deformity occurs, as athletes with a history of participation in soccer, basketball, and ice hockey during periods of skeletal growth have an increased prevalence of cam lesions compared to their nonathletic peers.[2,25,27] Following the closure of the physeal growth plate, the cam lesion does not progress.[1,2,25] It is hypothesized that repetitive physeal stress from these activities may predispose to developing a cam-type deformity because of the high shear forces applied to the femoral head.[22,27] Therefore, there may be a window during the period of skeletal maturation where the development of the bony morphology of the hip can be influenced by the chosen sport, creating a potential opportunity for injury prevention and avoidance of future hip pathology if the activity is moderated.

The bony morphology of female athletes, and specifically female dance athletes, is less well studied. One of the few studies of female athletes demonstrated that asymptomatic athletes at the collegiate level have an overall lower prevalence of radiographic FAI deformities than that previously reported for males, as well as a higher incidence of acetabular dysplasia.[18] The risk of hip pathology in female dance athletes is increased even in the absence of bony abnormalities as the normal demands of their activity result in hip impingement and cartilage compression.[7] Whether this repetitive stress may lead to compensatory bony abnormalities in female dance athletes, similar to those noted in male athletes, is unclear. Knowledge regarding the bony and soft tissue adaptations in this population of young female dancers is vital to understand the short- and long-term consequences for joint health.

With the increased prevalence of female athletes, understanding the etiology and risk factors for FAI has even greater importance. Specifically, the identification of modifiable risk factors, such as the influence of a specific activity, is vital, so that parents, athletes, and coaches may have the opportunity to mitigate the damaging effects of such conditions. The purpose of this investigation was to examine the radiographic findings of the hip in a population of young female dance athletes with FAI and to compare them with those of young female athletes involved in the more "conventional" sports of running, soccer, and ice hockey. We hypothesized that there will be a difference in the radiographic presentation of symptomatic FAI between sports.

METHODS

Data Collection and Reduction

After institutional review board approval (IRB-P00014793), a retrospective chart review was carried out between January 1, 2003, and August 31, 2015, in a division of sports medicine affiliated with a pediatric academic medical center. Electronic medical records via Orthoshare were systematically searched for all female patients, followed by the search words "FAI" OR "Femoral Acetabular Impingement" AND "pincer" OR "cam." This resulted in a total of 481 subjects. The diagnosis of FAI was made by the treating physician based on clinical history, physical examination, and radiologic findings. Subjects with no sport participation recorded and athletes participating in multiple sports were excluded, leaving 255 single-sport athletes. The exact level, hours per week, or years of athletic participation were not known. Prior to further exclusion criteria being applied, groups of ≤10 subjects were excluded to ensure adequate numbers for analysis. Athletes were excluded if they were ≥22 years old at the time of evaluation; had a history of prior hip surgery, Perthes disease, slipped capital femoral epiphysis, or congenital hip dysplasia; or had inadequate or incomplete radiographs. Patients who had undergone radiographic imaging with anteroposterior pelvis, as well as a lateral view of Dunn, cross-table, or frog-leg lateral, were included. Patients were excluded if radiographs were of poor quality or if coccyx-pubic symphysis distance was <1 cm, indicating excessive pelvic tilt as previously defined.[26] This left a total of 56 single-sport athletes for analysis (Figure 1).

Demographic data collected included age, weight, height, and sport(s) played. Those patients who reported specializing in only 1 sport were selected for final inclusion.

Radiographic Angle Measurements

Each of the following angles was measured: acetabular index (AI), lateral center-edge angle (LCEA), and alpha angle (AA). If false-profile views were available, the anterior center-edge angle (ACEA) was also measured. Nineteen dance athletes and 20 nondance athletes had false-profile views available for measurement. A single reviewer was used to evaluate radiographic angles, which was in keeping with other published studies that have evaluated radiographic FAI in athletes.[14,21] A sports medicine fellow who had undergone training in the measurement of radiographic angles by both a sports medicine physician and an attending musculoskeletal radiologist evaluated the radiographs. The fellow was unaware of the underlying type(s) of FAI diagnosed in each patient.

All angles were measured as previously described by Clohisy et al.[8] In addition, the presence or absence of both crossover and ischial spine signs was measured.

The definition of radiographic FAI morphology is still controversial, with different studies using varying criteria for identifying cam and pincer lesions.[14,18] Several morphological findings of FAI may also be found in a single patient,[14,24] and radiographic findings of FAI are found in asymptomatic hips.[14,17,18] Therefore, angles were objectively measured but not classified by FAI type. Both the symptomatic and asymptomatic sides were evaluated but not compared in this analysis.

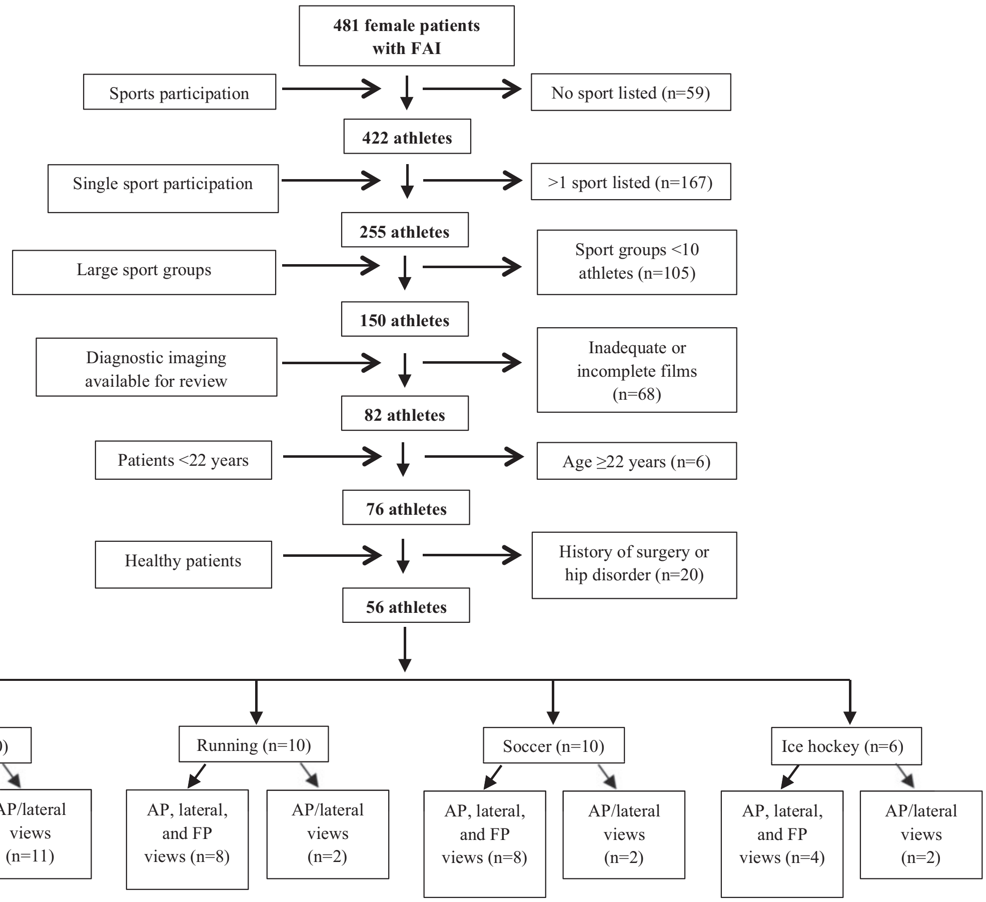

Figure 1. Identification of study cohort. AP, anteroposterior; FAI, femoroacetabular impingement; FP, false profile.

Statistical Analysis

Demographic characteristics, including age, weight, height, and sports, were analyzed descriptively. Dependent variables were AI, LCEA, AA, ACEA, crossover, and ischial spine signs. The independent variable was the sport the athlete participated in. Mean AI, LCEA, AA, and ACEA between dance and nondance athletes were compared using an independent *t* test when the data were normally distributed. The Mann-Whitney *U* test was employed when the data were not normally distributed. Dichotomized categorical variables, crossover and ischial spine signs, were analyzed between the groups by applying a chi-square test. Statistical significance was set as $P <$ .05 a priori. All analyses were performed using the IBM SPSS statistical software (version 21; SPSS Inc).

RESULTS

A total of 56 patients met the inclusion criteria. The study cohort consisted of 30 dance athletes and 26 nondance athletes (10 runners, 10 soccer players, and 6 ice hockey players). Mean age (±SD) of the dance athlete group was 16.8 ± 2.3 years; mean age of the nondance athlete group was 17.8 ± 2.2 years (P = .100). Both groups were similar in height, weight, and body mass index (Table 1).

Significant differences in angle measurements of bilateral hips were noted between the 2 groups (Table 2). The LCEA of dancers was significantly greater compared to that of nondancers (33.8° ± 6.7° vs 30.9° ± 5.8°, P = .016). There was no significant difference in AI between the 2 cohorts (5.0° ± 4.0° for dancers vs 5.9° ± 3.4° for nondancers, P = .195). AA was statistically lower in dancers than in nondancers (49.5° ± 6.0° vs 53.9° ± 7.3°, P = .001), but the ACEA of dancers was significantly greater compared to that of nondancers (36.0° ± 8.1° vs 32.3° ± 7.0°, P = .035). There were no statistically significant differences between dancers and nondancers in crossover and ischial spine signs (Table 3) (P = .707 and .093, respectively).

DISCUSSION

In this study, young female dance athletes with symptomatic FAI had different bony anatomy compared with that of nondance athletes involved in running, soccer, and ice hockey. Structural deformities of the hip are important to recognize, as they can both limit the ability to participate in athletic activities in the short term and lead to chronic

TABLE 1
Physical Characteristics of Dance and Nondance Athletes[a]

Variable	Dance Athletes (n = 30)	Nondance Athletes (n = 26)	*P* Value
Age, y	16.8 ± 2.3	17.8 ± 2.2	.100
Height, cm	161.7 ± 8.4	163.7 ± 5.5	.303
Weight, kg	55.5 ± 7.5	58.7 ± 8.0	.139
Body mass index	21.3 ± 3.4	21.8 ± 2.5	.521

[a]Data are reported as mean ± SD.

TABLE 2
Comparison of LCEA, AI, AA, and ACEA of Bilateral Hips Between Dance and Nondance Athletes[a]

Variable	Dance Athletes (n = 60)	Nondance Athletes (n = 52)	*P* Value
LCEA	33.8 ± 6.7	30.9 ± 5.8	.016[b]
AI	5.0 ± 4.0	5.9 ± 3.4	.195
AA	49.5 ± 6.0	53.9 ± 7.3	.001[b]
ACEA	36.0 ± 8.1	32.3 ± 7.0	.035[b]

[a]Data are reported in degrees as mean ± SD. AA, alpha angle; ACEA, anterior center-edge angle; AI, acetabular index; LCEA, lateral center-edge angle.
[b]Indicates statistically significant difference between groups.

TABLE 3
Presence of Positive Crossover or Ischial Spine Sign in Dance and Nondance Athlete Hips[a]

	Dance Athletes (n = 60)	Nondance Athletes (n = 52)	*P* Value
Crossover sign	36 (60)	33 (63.5)	.707
Ischial spine sign	29 (48.3)	17 (32.7)	.093

[a]Data are reported as n (%).

issues such as OA in the long term.[10,15] To date, the majority of studies on FAI have focused on male athletes and the increased prevalence of cam-type deformities in sports such as soccer and ice hockey.[1,5,11,21] Data on the female athlete with FAI are lacking, specifically on the young female dance athlete.

The mean AA in the nondance athlete group in this study was >50°, significantly higher than in the dance athlete group. Even using a more conservative cutoff for a cam lesion of an AA of >55°,[11,17] 18.3% (11/60) of dance athlete hips and 42.3% (22/52) of nondance athlete hips met the criteria for a cam lesion. The nondance athlete group consisted of runners and ice hockey and soccer athletes; therefore, these findings are consistent with prior studies on male athletes in these sports, specifically soccer and ice hockey, who have been found to have a high prevalence of cam-type FAI.[1,5,11,21] This suggests that not only male athletes but also female athletes who engage in these activities are at risk of developing the bony morphology consistent with cam-type FAI. A lower prevalence of cam-type deformity was noted by Kapron et al[18] in female asymptomatic volleyball, soccer, and track and field athletes than had previously been noted in male athletes; however, it was still the most common FAI finding. Further, acetabular undercoverage was more prevalent than either cam or pincer deformity in this group, which may help to explain why these athletes did not have clinical FAI, as this allows for greater range of movement before impingement occurs. Similarly, Johnson et al[17] found no significant difference in the AAs of female soccer players versus nonathlete female controls. Our athletes presented with symptoms consistent with hip impingement; therefore, we would expect the radiographic findings to reflect this with more evidence of radiographic FAI and/or less global acetabular coverage than in asymptomatic athletes.

The LCEA and ACEA were within normal limits in the dance athletes but were significantly increased compared to those of nondance athletes, indicating more global overcoverage. In addition, the AI did not differ between the 2 groups. In a recent study of the radiographic findings of the hips of elite professional dancers,[14] a very high rate of dysplasia or borderline dysplasia in at least 1 hip (89%) was noted. The mean AI in our group of dancers was also within the normal range. Given the findings of the study of Harris et al,[14] it is possible that those dancers with underlying dysplasia will "self-select" to progress onto higher levels of dance training, given that dysplasia will allow extreme ranges of motion to be obtained more easily at the hip joint.[31,32] It has been shown by Charbonnier et al[7] that hip impingement and subluxation occur at the extreme ranges of motion in advanced and professional-level dancers without evidence of morphologic FAI. These dancers, however, had an acetabular depth of <9 mm, which has been used as a criterion in multiple studies to define acetabular dysplasia,[14] and a mean femoral neck AA of 45.3°, which is 4° lower than in our study. Therefore, the "normal" radiographic findings in our dance athlete population may be a reflection of their amateur level and, possibly, a negative predictor of their likelihood to progress to a professional level, as their bony morphology, despite being within normal limits, may predispose them to becoming symptomatic given the high demands placed on the range of motion at the hip in this discipline.

Changes in soft tissue flexibility and increases in the range of motion at the hip can be modified with dance training.[4] Dancers tend to have greater hip external rotation than do nondancers, likely due to both soft tissue and bony adaptations through growth.[12,19] The differences noted require further investigation to determine whether the sport (dance) influences changes in the hip joint in these young athletes or merely predisposes them to a higher risk of symptomatology. The degree of femoral torsion in young dancers has been shown to be decreased in those who train for 6 hours per week or more during the 11- to 14-year age range.[13] A study of older dancers (18-30 years) found that they were capable of greater supine turnout and had decreased femoral torsion compared to that of nondancers.[29] Reduced femoral torsion is associated with passive hip external rotation,[9] a position frequently found in classical ballet. Passive range of motion is a function of both bony morphology and ligamentous/capsular restraints, and hip impingement in the dance population has been shown in motion-capture studies of selected dance positions even in the absence of radiographic plain film evidence of FAI.[7] While impingement is possible in all hips, in dance athletes the demands of their activity may increase the likelihood of symptoms even in the absence of currently defined bony abnormalities. It is therefore imperative to identify possible factors, either within or between chosen sports, that may lead to irreversible changes in the bony morphology of the hip.

The presence of a crossover or ischial spine sign was not significantly different between the groups in our study. Another study of athletes used the crossover sign to determine the presence of acetabular retroversion, a finding that can predispose to pincer FAI, and found this in 10% of female and 27% of male soccer players.[11] While these radiographic signs are helpful for determining the presence of acetabular anteversion or retroversion, a large element of error can be introduced by excessive pelvic tilt or rotation.[30] When noted in clinical practice, these findings must be taken into context with other radiographic measurements and the clinical examination, as well as consideration of the dynamic demands of the sport. In addition, other causes of hip pain in the adolescent athlete should be considered, such as hip flexor tendinitis, stress injuries, and pathology of the lumbar spine, before a diagnosis of FAI is made.

Limitations

Subjects were selected retrospectively from a database of athletes diagnosed with FAI. Therefore, these findings are not generalizable to the asymptomatic athlete without hip pain. The age range included both skeletally immature and mature athletes. Given the findings by Siebenrock et al,[25,27] which suggest that bony adaptations occur prior to skeletal maturity and do not progress after this has been reached, future studies should focus either on looking at these 2 groups separately or on following skeletally immature athletes longitudinally. Sport participation was determined by chart review; therefore, it is possible athletes participated in other sports in addition to those listed. We attempted to select only those patients who listed 1 sport, in order to most accurately identify single-sport athletes. The overall number of subjects was relatively low ($N = 56$) but was comparable to other contemporary studies.[15,21] In our study, 1 reviewer was used when determining radiographic angles, and while some studies have shown high interobserver reliability for measurement of radiographic findings of FAI,[3] others have found that accuracy does not necessarily increase with multiple reviewers.[23] The reviewer was blinded to the underlying diagnosis regarding type of FAI. Future studies, including of asymptomatic young dance athletes, are needed to more fully elucidate the underlying bony anatomy of this population. Given the wide and varied range of causes of hip pain that can occur, future studies including asymptomatic and symptomatic young dance athletes are needed to more fully elucidate the underlying bony anatomy of this population and help to identify the structural pathology that may predispose to clinical hip impingement and joint damage.

CONCLUSION

In this cohort of young female single-sport athletes with a diagnosis of FAI, significant differences in radiographic abnormalities were seen between sport groups. Running, soccer, and ice hockey athletes had significantly higher AA, while dance athletes had higher LCEA and ACEA. Specifically, in the discipline of dance, even normal bony morphology can result in symptoms and may be a negative predictor of progression to a higher level. It is unclear if these bony morphological changes develop as a result of participation in the chosen activity or if the demands of the activity may predispose patients with certain underlying anatomic findings to become symptomatic. Future studies of asymptomatic young dance athletes, with adequate follow-up, are needed to more fully elucidate the development of the hip bony anatomy of this population and the possible influence of sporting activity on the development of the hip joint. This information is vital to aid in the counsel of young athletes regarding sport participation and to minimize the risk of future hip injury.

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